

Biomining

The INEEL has a long-standing multi-disciplinary program in biological mining. Biomining research has included biohydrometallurgy or biological approaches to the extracting and recovering of metal from ores, controlling acid drainage, and processing biological phosphate minerals. Initial work focused on cobalt and other metals extraction and recovery from low grade ores but was expanded to include sulfidic ores such as gold, copper, zinc, and nickel.



Control of sulfide mineral leaching requires understanding the microbial ecology of these environments. Microbial techniques used to speciate and enumerate microbes include a special overlay plating method to isolate bacteria typically difficult to grow, 16S rDNA techniques, and fluorescent in situ hybridization. These methods can identify and enumerate mesophilic, moderate thermophilic, and extreme

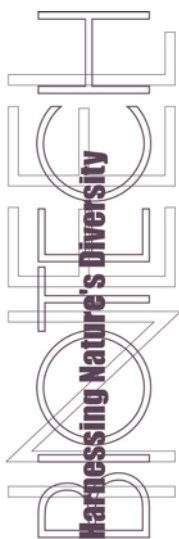
thermophilic organisms. These techniques are used to monitor microbial populations and population shifts due to such environmental changes as pH, temperature, and dissolved oxygen shifts. Such fluctuations in stir tank and column processes, and in heap and dump leaching systems are thereby understood and controlled.

INEEL researchers developed biological strategies for leaching of arsenopyrite ores (including the use of genetic engineering to improve arsenic resistance in acidophilic bacteria), techniques for acid rock drainage mitigation, approaches to

cyanide degradation in gold mining operations, bioprocesses for selenium and chromium reduction, and options for metal sorption from process or waste waters. The INEEL organized and hosted the International Biohydrometallurgy Symposium at Jackson Hole, Wyoming, in both 1989 and 1993.

Bioprocessing of phosphate containing minerals to separate phosphate has been studied. Microbes, for example *Pseudomonas cepacia*, that promote separation of phosphate from gangue material have been isolated, characterized, and applied.





[www.inel.gov/
capabilities/biotechnologies](http://www.inel.gov/capabilities/biotechnologies)

Technical Contact

F. F. Roberto, Ph.D.

Idaho National Engineering and
Environmental Laboratory
P.O. Box 1625, Idaho Falls, ID
83415-2203

Phone - 208-526-1096
Fax - 208-526-0828
Email - ffr@inel.gov

Management Contact

Dr. Melinda Hamilton

Idaho National Engineering and
Environmental Laboratory
P.O. Box 1625, Idaho Falls, ID
83415-2203

Phone - 208-526-0948
Fax - 208-526-0828
Email - hmn@inel.gov

Selected Publications/Presentations/Patents

F. F. Roberto, "Bioleaching of Minerals," (Invited chapter) *The Encyclopedia of Environmental Microbiology*, G. Bitton and R. S. Burlage (Eds), J. Wiley and Sons, Inc., 2001.

D. B. Johnson, D. A. Body, T. A. M. Bridge, D. F. Bruhn, and F. F. Roberto, "Biodiversity of Acidophilic Moderate Thermopiles Isolated From Two Sites in Yellowstone National Park and Their Roles in the Dissimilatory Oxido-Reduction of Iron," *Thermopiles: Biodiversity, Ecology and Evolution*, A. L. Reysenback, M. Voytek, R. Mancinelli (Eds), Plenum Publishing Co., New York, 2001, pp. 23–39.

R. M. Lehman, F. F. Roberto, D. Early, D. F. Bruhn, S. E. Brink, S. P. O'Connell, M. E. Delwiche, F. S. Colwell, "Attached and Unattached Bacterial Communities in Closely-Paired Groundwater and Corehole Samples from an Acidic, Crystalline Rock Aquifer," *Appl Environ Microbiol.* 67(5), 2001, pp. 2095–2106.

D. F. Bruhn, D. N. Thompson, and K. S. Noah, "Microbial Ecology Assessment of a Mixed Copper Oxide/Sulfide Dump Heap Leach Operation." Biohydrometallurgy and the Environment Toward the Mining of the 21st Century; Part A, Eds: R. Amids and A. Ballester, *International Biohydrometallurgy Symposium, El Escorial*, Spain, June 1999, pp. 799–808.

D. B. Johnson and F. F. Roberto, "Heterotrophic Acidophiles and Their Roles in the Bioleaching of Sulfide Minerals," *Chapter 13, Biomining: Theory, Microbes and Industrial Processes*, D. E. Rawlings, ed., R. G. Landes Co., publisher, 1997.

D. F. Bruhn, J. Li, F. F. Roberto, S. Silver and B. P. Rosen, "Arsenic Resistance Operon of IncN Plasmid R46," *FEMS Microbiol. Lett.*, **139**, 1996, pp. 149–153.

D. B. Johnson, P. Bacelar-Nicolau, D. Bruhn and F. F. Roberto, "Iron Oxidizing Heterotrophic Acidophiles: Ubiquitous Novel Bacteria in Leaching Environments," *Biohydrometallurgical Processing*, T. Vargas, C. A. Jerez, J. V. Wiertz, and H. Toledo, eds., University of Chile, 1995, pp. 47–56.

R. D. Rogers and J. H. Wolfram, "Microbial Solubilization of Phosphate," Patent 5,256,544, Issued October 26, 1993.

